

E12

(12) UK Patent Application (19) GB (11) 2 068 014 A

(21) Application No 8101757
 (22) Date of filing 21 Jan 1981
 (30) Priority data
 (31) 115116
 (32) 24 Jan 1980
 (33) United States of America (US)

(43) Application published
 5 Aug 1981

(51) INT CL³
 C10J 3/62

(52) Domestic classification
 C5E 501 502

(56) Documents cited
 GB 2055890A
 GB 2009779A
 GB 1447546
 GB 1017527
 GB 858032
 GB 747061

(58) Field of search
 C5E

(71) Applicants
 Tosco Corporation, 10100
 Santa Monica Boulevard,
 Los Angeles, California
 90067, United States of
 America

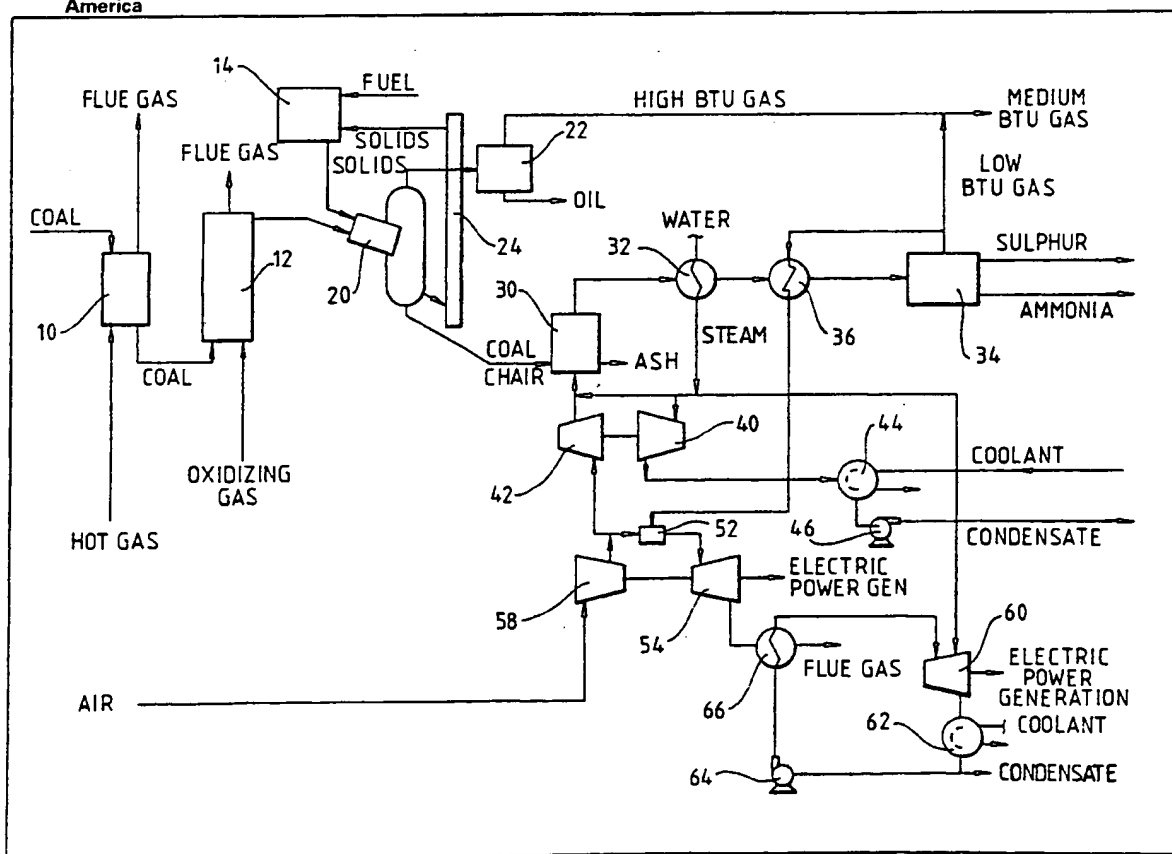
(72) Inventors
 Douglas H. Cortez,
 James J. Humphries

(74) Agents
 Gill, Jennings & Every,
 53/64 Chancery Lane,
 London WC2A 1HN

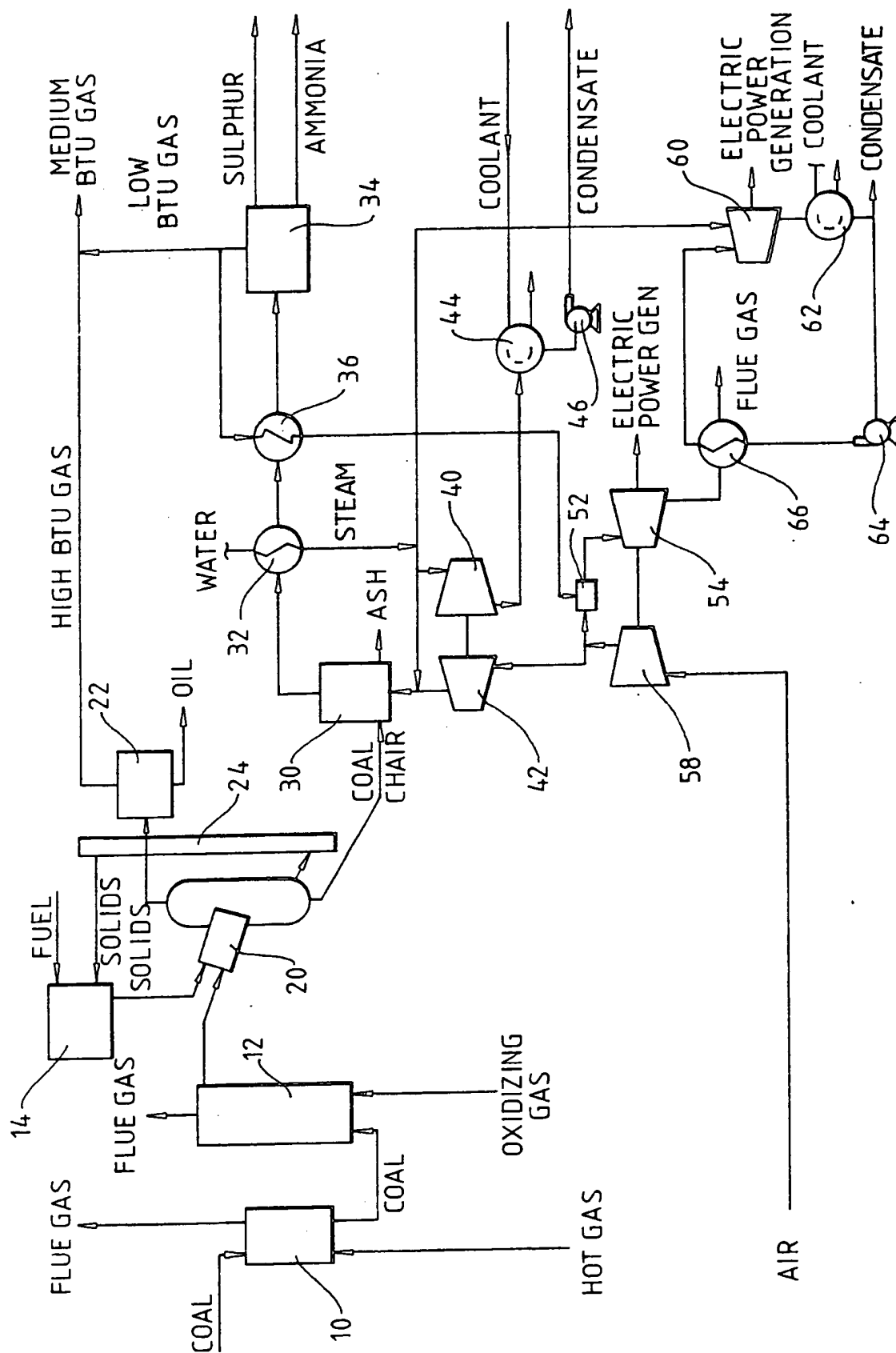
(54) Process for the gasification of coal

(57) Coal particles are dried in a drying zone 10 and are then preheated in a preheater 12 to a temperature just below the pyrolysis temperature. Next the coal is pyrolysed in a retort 20 by contacting

it with heat carrying solids and in a non-oxidising atmosphere, to remove substantially all of the tar-forming volatile combustible matter from the coal particles and produce substantially tar-free coal char particles and also volatile vapours and condensable gases. The devolatilised tar-free char particles are then contacted with steam and an oxygen — containing gas in a gasifier 30. The gasification in the gasifier 30 produces a combustible gas which is tar-free and is ideally suited for combustion, for example to produce combustion gases for driving a gas turbine 54.



GB2 068 014 A



SPECIFICATION

Process for the gasification of coal

For some time there has been interest in utilizing coal to produce combustible gases which, inter alia, may be used to generate electric power. One method which has been suggested for converting coal to combustible gases involves gasifying coal with steam and oxygen and combusting the resulting gas in a gas combustion turbine to generate electric power. The gas produced by this type of coal gasification must be scrubbed to remove contaminants and the method has many drawbacks. For example, the gas contains varying amounts of volatile combustible matter (VCM) and some of this VCM is coal tar which is gooey and difficult to handle. The tar, in combination with certain dust-like material which is produced during the gasification of coal, is present in the gas produced by the gasification. Both of these materials plug and foul equipment through which the gas flows and this makes it extremely difficult to recover heat from the gas produced from the coal. In addition, if the gasification step is combined with cycle powered generation, the operation of the gasification apparatus and combined cycle powered plant are interdependent so that start up and control of the integrated plant is impossible without external fuel and auxiliary equipment which adds extensively to the cost.

Another proposed method for treating coal is described in an article entitled "Production of Low Btu Gas Involving Coal Pyrolysis and Gasification", by Wen et al. of the Chemical Engineering Department of West Virginia University, Morgantown, West Virginia 26506 (pages 36 to 54). In this article, it is proposed to pyrolyze coal in a fluidized bed at approximately 760°C. The char produced from the pyrolysis step is separated from the effluent gas and the char is then reacted with air and steam to produce the fluidizing gases from the coal-pyrolyzer. However, it is emphasized in the article that in order to gasify the char, raw coal must be added to the char feed in order to maintain the correct temperature in the gasifier and, additionally, in order to produce a sufficient amount of gas to fluidize the coal. Because of the manner in which the coal is pyrolyzed in the fluidized bed and because raw coal must be added to the pyrolyzed char the method proposed by Wen et al. would have most of the drawbacks of the prior art method described above.

Another prior art method is disclosed in United States Patent No. 1,758,630 (Trent) in which it is proposed to pyrolyze coal, in a fluidized bed, to remove all of the volatile combustible matter from the coal and, thereafter, to contact the resultant coal char with air and steam to produce a producer gas. This proposed method is also inefficient due, in part, to the manner in which the coal char is produced. Insofar as we are aware, none of the prior art methods have been concerned with producing a partially devolatilized coal char product by pyrolyzing the coal in such a manner that the char is ideally suited for gasification. The gasification of such coal char produces a gas which is tar-free and ideally suited for combustion, particularly when mixed with the gaseous vapours (i.e. after the condensable products have been removed) produced in the pyrolysis step.

Accordingly, the main object of the present invention is to provide a simple and improved process for the gasification of coal to produce a combustible gas from a particular form of partially devolatilized coal char by gasifying the char with steam and an oxygen containing gas.

To this end, according to this invention, a process for the gasification of coal by pyrolyzing coal to produce coal char and gasifying the resultant coal char with steam and an oxygen-containing gas is characterized by the following steps:—

pyrolyzing, in a pyrolysis zone, coal particles containing volatile combustible matter by contacting the coal particles, in a non-oxidizing atmosphere, with heat-carrying solids at a temperature from 370°C to 816°C, to remove substantially all of the tar-forming volatile combustible matter from the coal particles and to produce volatile vapours, condensable gases and partially devolatilized coal char particles, the remaining volatile combustible matter in the partially devolatilized coal char particles containing substantially no condensable tar material, and being substantially non-swelling;

separating the partially devolatilized coal char particles from the heat-carrying solids and from the volatile vapours and condensable gases;

transferring the separated partially devolatilized coal char particles to a gasifying zone;

contacting the partially devolatilized coal char particles in the gasifying zone with steam and an oxygen-containing gas at a temperature from 538°C to 1371°C to volatilize the remaining volatile combustible matter from the partially devolatilized coal char particles and to react the carbon in the partially devolatilized coal char particles with the steam and thus producing substantially tar-free combustible gas and ash; and,

separating the substantially tar-free combustible gas from the ash.

In this process, the coal is pyrolyzed in a particular manner to produce a partially devolatilized coal char which is ideally suited for gasification with steam and an oxygen-containing gas to produce a tar free gas. The partially devolatilized char is substantially non-swelling, has a relatively high bulk density and is highly reactive to gasification with steam. In addition to the valuable partially devolatilized char produced in the pyrolysis step, there are also produced volatile vapours and condensable gases. The volatile vapours may be used for their heating value and the condensable gases, when condensed, are valuable hydrocarbon liquids which may be used in the petro-chemical or petroleum industries or burned for their heating value.

The pyrolysis step is conducted in a pyrolysis zone in a critical manner which includes contacting coal particles with heat-carrying solids in a non-oxidizing atmosphere and, preferably, in the absence of other extraneous gases. The heat-carrying solids contact the dried coal particles so that the heat-carrying solids heat the coal particles to the desired pyrolysis temperature, e.g. from 371°C to 816°C and, preferably, from 427°C to 649°C, e.g. 427°C to 538°C. The coal particles are heated by the heat-carrying solids for a sufficient length of time and at a sufficient temperature to remove substantially all of the tar-forming VCM from said coal particles. There are produced in the pyrolysis zone, volatile vapours, condensable gases (i.e. hydrocarbons which, at room temperature, are liquids) and partially devolatilized coal char particles, the remaining VCM in the partially devolatilized coal char particles containing substantially no condensable tar material. We have found that such partially devolatilized coal char particles are excellent for gasification with steam because the coal char particles contain some and preferably substantially all of the non-tar forming VCM but substantially no tar-forming VCM. Moreover, the partially devolatilized coal char particles have a relatively high bulk density (e.g. above 320 kg/Cu m and preferably above 400 kg/Cu m) which also makes them very valuable as a gasification feedstock. Furthermore, the partially devolatilized coal char particles produced in accordance with our invention are highly reactive, i.e. such coal char particles require less steam to gasify them.

The combustible gas produced by gasifying partially devolatilized coal char particles has many applications. For example, the combustible gas produced by gasifying partially devolatilized char with steam and air (as opposed to pure oxygen) may be mixed with the volatile vapours produced in the pyrolysis zone to produce a gas of medium calorific value (i.e. a gas with a heating value in the range of 7450—22350 kJ/Cu m) which can be burned in existing heaters and furnaces without modifying the burners or de-rating equipment capacity. As is known in the art, it is impossible to produce a gas of medium calorific value by oxidizing the carbon in coal utilizing air as the oxidizing agent to raise the temperature. But since the volatile vapours produced in the pyrolysis step are not diluted with extraneous gases such as nitrogen, the process produces a medium calorific value gas in a very simple and inexpensive manner.

In addition to utilizing the combustible gas produced by the gasification of the partially devolatilized coal char to produce a medium calorific value gas, the combustible gas may also be used to generate electric power in a gas combustion turbine as well as being utilized to compress air and produced steam used in the gasification of the partially devolatilized coal char without fouling downstream equipment with contaminants such as tar which, as noted previously, complicates the recovery of heat from the gasification product. In addition, such use of the gasification product in the manner described above eliminates the necessity of external fuel and certain auxiliary equipment which would make the process relatively expensive and, perhaps, make the process economically unviable.

In general, it is preferred that prior to the pyrolysis of the coal, the raw coal is ground to form particles therefrom of, for example, sizes of from -13 mm to -3 mm. After the coal has been ground it is also preferred if the moisture from the coal is removed in a preheating step by, for example, heating the coal particles at a temperature of from 93°C to 316°C and for a sufficient length of time to remove substantially all of the moisture. If the coal is a caking or Eastern U.S.A. type coal, it is generally preferred that the coal be pretreated either before, after, or during the drying step, to decake the coal by contacting the coal with an oxidizing gas containing from, for example, 1% to 20% by volume, of oxygen as described in U.S. Patent No. 3,184,293. In addition to decaking the coal, such a step will remove substantially all the moisture from the coal. After the drying step and/or pretreating step, most coals will contain anywhere from 20% to as much as 50% by weight of VCM and from 75% to 50% fixed carbon.

In the pyrolysis step, the VCM which contains the tar is substantially reduced and, in general, the amount of VCM after the pyrolysis step contained in the coal will be between 10 weight % and 20 weight %, excluding moisture. The specific temperature and time of the pyrolysis step are not particularly critical but in general, the pyrolysis step may be conducted anywhere from 371°C to 816°C with the preferred temperature range being from 427°C to 649°C and the most preferred temperature range being from 427°C to 538°C. The length of time necessary to conduct the pyrolysis step will also vary greatly depending upon the temperature and the amount of VCM in the raw coal. If, for example, a temperature of 510°C is used and the coal contains approximately 40 weight % to 45 weight % of VCM a five minute resident time is sufficient to produce a partially devolatilized coal char in which the VCM contained in the partially devolatilized coal char has substantially no tar therein.

The pyrolysis step is also conducted in a non-oxidizing atmosphere and, preferably, in the absence of extraneous gases so that the vapours produced during the pyrolysis step will not be diluted and the volatile vapours, after the condensable gases have been removed, will have a relatively high calorific value of for example, 29,800 kJ per cubic metre after the condensable gases have been removed.

The dried coal particles are pyrolyzed, in the non-oxidizing atmosphere, by contacting the dried coal particles with heat-carrying solids which should be inert to the coal, partially devolatilized char, and the vapours produced during the pyrolysis step. The particular type of heat-carrying solids utilized to heat the coal particles may vary widely and have any desired shape. For example, the heat-carrying solids may be of metal or ceramic and may have a ball-like shape of approximately 6 mm to 13 mm diameter. In the preferred exemplary embodiment the heat-carrying solids are alumina balls of approximately 13 mm diameter. In addition, for easy separation, the heat-carrying solids should have a

size which is substantially different than the size of the partially devolatilized char particles. In general, it is preferred if the heat-carrying solids have a diameter which is greater than the diameter of the partially devolatilized char particles.

In order to conduct heat from the heat-carrying solids to the coal particles, the heat-carrying solids must contact the coal particles to transmit their heat thereto. It is preferred for the pyrolysis step to be conducted in a rotating retort. The rotational speed of the retort is sufficient to mix the heat-carrying solids with the coal particles in order to obtain good heat transfer between the coal particles and heat-carrying solids. The specific rotational speed of the retort may vary greatly and is dependent upon the diameter of the rotor. After pyrolysis is complete the heat-carrying solids and the partially devolatilized char particles are separated as are the volatile vapours and the condensable gases produced during the pyrolysis step.

The partially devolatilized char is then transferred to a gasification zone where the char is gasified with steam. The conditions under which the gasification step is conducted are not critical and, in general, are known in the art. The temperature in the gasification zone will be sufficient to react the steam with the carbon in the partially devolatilized coal char to form a combustible gas consisting predominantly of carbon monoxide and hydrogen. The temperature may vary widely and may range from as low as 538°C to as high as 1371°C, the specific temperature used will depend primarily on whether a gasification catalyst is added to the gasification zone. If a gasification catalyst is utilized the temperature will range between 538°C and 816°C or 871°C whereas if the reaction is conducted in the absence of the gasification catalyst (i.e. a thermal reaction) the temperature will be in excess of 871°C for example, from 871°C to 1093°C or even higher (e.g. 1371°C).

As is the case with the temperature of the gasification reaction, the pressure used to gasify the carbon with steam is also not critical and may vary widely from ambient pressure to 138 bar there being no theoretical upper limit on the pressure.

As noted, the gasification reaction may be conducted with or without a catalyst and if a catalyst is used the temperature will vary from 538°C to 816°C. The gasification catalysts are generally well-known in the art and therefore no detailed exemplification thereof will be given. However, alkali metal salts, for example, sodium, potassium and lithium, are those generally used and include the hydroxide salts, the carbonate salts, the oxide salts, sulfate salts, and sulfide salts.

The concentration of the catalyst in the gasification zone may also vary widely and, in general, will range from about 1 weight % to about 50 weight % based on the weight of the total solids in the gasification zone. The preferred concentration of catalyst is from about 4 or 5 weight % to as high as 20 or 30 weight %.

The amount of steam used to gasify the partially devolatilized coal char should be sufficient to substantially gasify all of the fixed carbon contained in the char. In general, the amount of steam will be between 0.1 to 1 part by weight of steam per hour per one part by weight of carbon in the gasification zone and the more preferred range is between 0.2 and 0.6 parts by weight.

The temperature in the gasification zone is maintained by introducing an oxygen containing gas such as air into the zone to oxidize a portion of the carbon contained in the partially devolatilized coal char, such oxidation reaction being exothermic, the amount of oxygen introduced being sufficient to maintain the temperature at the desired level.

An example of a process in accordance with the invention will now be described with reference to the accompanying drawing which is a flow diagram.

Specifically referring to the drawing, in the preferred example coal particles, prior to pyrolysis, are introduced into the top of a drying zone 10 and a hot gas is introduced at the bottom of the drying zone 10, the approximate drying temperature in the zone 10 being 121°C. After the drying step, and using Wyodak coal, the coal composition consisted of 7.6 wt. % ash, 43.9 wt. % volatile material, and 48.5 % carbon.

It should be noted, that if an Eastern United States coal is utilized then it is sometimes necessary to have a pretreatment step either before or after removing the moisture from the coal. This pretreatment step is to decake the coal and, in general, as is known in the art, consists in contacting the coal with an oxidizing gas.

After the drying step, the dried coal is passed to a preheating zone 12 where the coal is heated to slightly below the pyrolysis temperature.

In the preferred example, the preheating temperature is about 230°C and the oxidizing gas utilized to preheat the coal particles is preferably a gas containing about 10 volume % oxygen. The coal particles leaving the preheating zone 12 have approximately the same composition as the dried coal particles entering the preheating zone 12.

After the coal particles have reached a temperature of 230°C they are passed to a retort 20 where the pyrolysis step is conducted in the absence of oxygen and other non-extraneous gases. In the retort 20 the coal particles are heated to a temperature of from 371°C to 816°C (in the preferred example from 427°C to 538°C). Heat-carrying solids are used to heat the coal particles in the retort 20. The heat-carrying solids are preferably ceramic balls which are heated to an appropriate temperature in a solids heater 14, the ceramic balls reaching a temperature of 650°C—705°C depending upon the temperature at which the pyrolysis step is required to be conducted. The weight ratio of the heat-

carrying solids to the coal is 2.8 : 1.

The heat-carrying solids and coal particles are both passed to the retort 20 which rotates about its axis at a relatively slow speed, for example three revolutions per minute in order to mix the solids with the coal. After the pyrolysis is completed to the point desired, the volatile vapours and condensable gases, the heat-carrying solids, and the coal char are separated. The separated solids are returned via a lifter 24 to the solids heater 14 and the partially devolatilized coal char particles are conveyed to a gasifier 30. The volatile vapours and condensable gases are transported to an oil and gas recovery zone 22 where the higher calorific value gas is separated from the lower boiling oils and, if desired, sulphur is removed. In the following Table 1 is set forth the composition of the partially devolatilized char resulting from three different runs, the temperature of the retort during the runs being set out in the top column of Table 1.

TABLE 1
CHAR COMPOSITION

Run No.	1	2	3
Retort Temperature	427°C	482°C	521°C
<i>Proximate wt. % of char</i>			
Moisture	0.0	0.0	0.0
Ash	12.4	10.0	9.8
Volatile Combustible Matter	25.3	19.7	15.9
Fixed Carbon	62.3	70.3	74.3
	100.0	100.0	100.0
<i>Ultimate (wt. %)</i>			
Carbon	68.8	74.7	77.5
Hydrogen	3.4	3.0	2.9
Oxygen	13.3	11.8	8.3
Nitrogen	1.0	1.2	1.3
Sulphur	0.5	0.2	0.3
Ash	12.4	10.0	9.8
<i>Other data</i>			
Equilibrium Moisture (wt. %)	10.0	10.8	9.9
Hardgrove Grindability	78.2	49.1	45.6
<i>Calorific values</i>			
Gross, kJ/kg	27,507	29,214	30,151
Nett kJ/kg	26,786	28,563	29,523
<i>Bulk Density (6 mm × 0)</i>			
Packed kg/Cu m	820.2	781.8	765.8

In Table 1, run 1 used a Wyodak coal which had a different composition from the Wyodak coal used in each of runs 2 and 3.

Tables 2 and 3, respectively, show the composition of the oil and gases in the pyrolysis step of runs 1 to 3.

TABLE 2
OIL PROPERTIES

Oil Properties Run No.	Retort Temperature		
	1	2	3
<i>Ultimate (wt. %)</i>			
Carbon	81.4	80.7	80.9
Hydrogen	9.3	9.1	8.7
Oxygen	8.3	9.4	9.3
Nitrogen	0.48	0.7	0.7
Sulphur	0.43	0.2	0.2
Chlorine	0.0	0.0	0.0
Ash	0.0	0.2	0.1
Total	99.91	100.3	99.9
<i>Calorific Values</i>			
Gross kJ/kg	38,588	37,720	37,132
Nett kJ/kg	36,611	35,755	35,262
<i>API Gravity</i>			
Primary Oil	7.9	4.5	1.9
Calculated, with C ₄	13.2	12.1	6.2
and heavier components of gas added			
<i>Pour Point (°C)</i>	32	38	35
Conradson Carbon (wt. %)	7.6	9.9	11.4
<i>Distillation (vol. %)</i>			
2.5	211°C	216°C	199°C
10	254	246	207
20	302	288	235
30	341	329	285
40	377	371	338
50	407	413	385
<i>Viscosity (SUS)</i>			
82°C	122	123	128
99°C	63	66	69

TABLE 3
GAS ANALYSES

Run No.	Retort Temperature		
	1	2	3
<i>Component (mole %)</i>			
H ₂	0.8	1.0	7.8
CO	18.0	17.3	18.4
CO ₂	51.1	42.3	36.4
H ₂ S	1.7	1.3	0.3
C ₁	16.9	22.0	24.9
C ₂	3.6	4.7	4.4
C ₂ -(ethylene)	1.9	1.9	2.4
C ₃	1.3	2.2	1.2
C ₃ -(propylene)	1.6	3.7	1.6
iC ₄	0.1	0.1	0.0
C ₄	0.3	2.0	1.1
C ₅	1.0	1.8	0.7
C ₆	0.7	0.6	0.4
C ₇	0.5	0.1	0.3
C ₈₊	0.2	0.0	0.1
Total	99.7	101.0	100.0
Average Molecular weight	35.9	35.0	30.6
Weight Percent Carbon	40.5	45.9	44.7
Calorific Values, Calculated			
Gross kJ/Cu m	19,897	26,715	23,474
Nett kJ/Cu m	18,406	24,703	21,610
Calculated with CO ₂ and H ₂ S removed			
Gross kJ/Cu m	41,470	45,979	37,074
Nett kJ/Cu m	38,340	42,402	34,279

The coal char particles from the retort 20 are transferred to the gasifier 30. The gasifier 30 may be any air blow gasifier, such as a fluidized bed entrained flow, or moving bed, each with or without catalysts. The temperature at which gasification takes place is not particularly critical.

5 In the preferred example, the gasifier 30 is an air blow fluidized bed gasifier operated at moderate pressure (e.g. 1.38 to 13.8 bar). The char enters the gasifier 30 at a temperature of between 454°—482°C. The air and steam supplied to the gasifier 30 has a temperature of 316°C and the 5

steam to O₂ ratio is approximately 2.6. The gasification produces a combustible gas having a temperature of approximately 927°C and is removed from the top of the gasifier. The resulting ash is removed from the bottom for disposal. The gas leaves the gasifier 30 and passes through a heat exchanger 32 which generates steam, a portion of which is used in the gasifier 30. The combustible gas continues to a byproduct recovery unit 34 which by any conventional process removes undesired constituents such as sulphur and ammonia and results in the desired low calorific value combustible gas. The combustible gas has a composition of approximately 25.3% H₂, 20.9% CO, 11.1% CO₂, 1.7% CH₄ and 41% N₂ with a gross heating value of approximately 6185 kJ/Cu m. By low calorific value gas, is meant a gas which contains very little if any high calorific value gases, such as methane, and a relatively large amount of low calorific value gases, such as H₂ and CO.

The low calorific value gas has many uses and, in one preferred example, the low calorific value gas is mixed with high calorific value gas from the pyrolysis zone to produce a medium calorific value gas having a calorific value of about 9315 kJ/Cu m.

In another preferred embodiment, at least a portion of the low calorific value gas passes through a heat exchanger 36 which assists in cooling the combustible gas flowing to the byproduct recovery unit 34, and which correspondingly reheats the gas prior to its introduction into a combustion burner 52 adjacent to a gas turbine 54. It is desirable that the gas be introduced into the burner 52 at approximately 204°C and 19.29 bar.

Air is pressurized to 13.78 bar in a compressor 58, a portion of this air being fed to another air compressor 42 which in turn pressurizes the air further (to 27.56 bar) and this pressurized air is mixed with steam and used in the gasifier 30. It should be noted that the air compressor 42, which applies high pressure air to the gasifier 30, is powered by a turbine 40 from a portion of the steam generated in the heat exchanger 32. The expended steam from the turbine 40 flows through a condenser 44 and is discharged by a pump 46 as condensate.

Another portion of the pressurized air from an air compressor 58 is fed to the combustion burner 52 for use in combustion turbine 54 which will generate electric power as well as driving air compressor 58.

If desired, a portion of the steam generated in the heat exchanger 32 may optionally be fed to an auxiliary steam turbine 60 for supplemental power generation. The steam discharged from the turbine 60 passes through a condenser 62 and may either be discharged as condensate or, alternatively, the condensate is fed to a heat exchanger 66 via a pump 64 to regenerate steam for recycling into the turbine 60. The heat exchanger 66 is supplied with the discharged, but still hot, flue gas from the gas turbine 54.

CLAIMS

1. A process for the gasification of coal by pyrolyzing coal to produce coal char and gasifying the resultant coal char with steam and an oxygen-containing gas, characterized by the following steps:—

pyrolyzing, in a pyrolysis zone, coal particles containing volatile combustible matter by contacting the coal particles, in a non-oxidizing atmosphere, with heat-carrying solids at a temperature from 371°C to 816°C., to remove substantially all of the tar-forming volatile combustible matter from the coal particles and to produce volatile vapours, condensable gases and partially devolatilized coal char particles, the remaining volatile combustible matter in the partially devolatilized coal char particles containing substantially no condensable tar material and being substantially non-swelling;

separating the partially devolatilized coal char particles from the heat-carrying solids and from the volatile vapours and condensable gases;

transferring the separated partially devolatilized coal char particles to a gasifying zone;

contacting the partially devolatilized coal char particles in the gasifying zone with steam and oxygen containing gas at a temperature from 538°C to 1371°C to volatilize the remaining volatile combustible matter from the partially devolatilized coal char particles and to react the carbon in the partially devolatilized coal char particles with the steam and thus producing substantially tar-free combustible gas and ash; and,

separating the substantially tar-free combustible gas from the ash.

2. A process according to Claim 1, in which the coal particles are pyrolyzed at a temperature of from 427°C to 538°C.

3. A process according to Claim 1 or Claim 2, characterized by the further step of prior to the pyrolyzing step, heating the coal particles in a drying zone at a temperature from 93°C to 316°C to remove substantially all the moisture from the coal particles without removing any substantial portion of the volatile combustible matter from the coal particles.

4. A process according to any one of Claims 1 to 3, characterized by the further step of reheating the separated heat-carrying solids in a solids reheater and recycling the reheated solids back to the pyrolysis zone.

5. A process according to any one of Claims 1 to 4, characterized by the further step of separating, in a recovery zone, the volatile vapours and condensable gases produced in the pyrolysis zone to form therefrom oil and gas of high calorific value.

6. A process according to any one of the preceding Claims, characterized by the further steps of

passing the substantially tar-free combustible gas from the gasifying zone through a heat exchanger to exchange heat with water to form steam; and

feeding a portion of the steam from the heat exchanger to the gasifying zone.

- 5 7. A process according to Claim 6, characterized by the further step of feeding another portion of the steam from the heat exchanger to a steam turbine which drives a compressor which feeds the oxygen-containing gas to the gasifying zone. 5

8. A process according to Claim 6 or Claim 7, characterized by the further step of feeding another portion of the steam from the heat exchanger to a steam turbine for generating electric power.

- 10 9. A process according to any one of the preceding Claims, characterized by the further step of passing the substantially tar-free combustible gas from the gasifying zone to a by-product recovery unit to remove sulphur and ammonia from the combustible gas and form a clean burning gas of low calorific value. 10.

10. A process according to Claim 9, characterized by the further step of mixing a portion of the gas of low calorific value from the by-product recovery unit with the gas of high calorific value from the recovery zone to form gas of a medium calorific value. 15

11. A process according to Claim 9, or Claim 10, characterized by the further steps of passing a portion of the gas of low calorific value from the by-product recovery unit to a burner where it is burnt to form combustion gas, and feeding the combustion gas to a combustion gas turbine for generating electric power.

- 20 12. A process according to Claim 1, substantially as described with reference to the accompanying drawing. 20